Vortex Activities in Diffuser Augmented Wind Turbines

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Study motivation

When a wind turbine is exposed to a stream of airflow, shed vortices are formed at different localities and of different size and intensities. These vortices may interact with each other or with some other features of the turbine.

Blade Tip Vortex (BTV) is known to have adverse impact to power generation efficiency in bare wind turbine. The shrouding of a Diffuser Augmented Wind Turbine (DAWT) imposes a confinement to BTV development, thus it is only logical to postulate that DAWT suppresses the BTV.

It is prudent to understand how shed vortices are developed and how they interact to narrow gaps similar to the gap between the blade tip and the inside diffuser wall (BTDWG), such as a honeycomb.

Methodology and Set-up

CFD Simulations:

Software: ANSYS Fluent Model: Transition SST (4 Eqn)

Flat Plate:	Length: 210 mm	AOA: 90° & 45°
Profiled Plate: NACA2414	Chord: 200 mm	AOA: 15°, 45° & 60°
Coarse Honeycomb:	1-D Porosity: 0.8	Length: 150 mm
Fine Honeycomb:	1-D Porosity: 0.5	Length: 150 mm

Results

Finding 1: Detaching Vortices – Same Size at Any Velocity

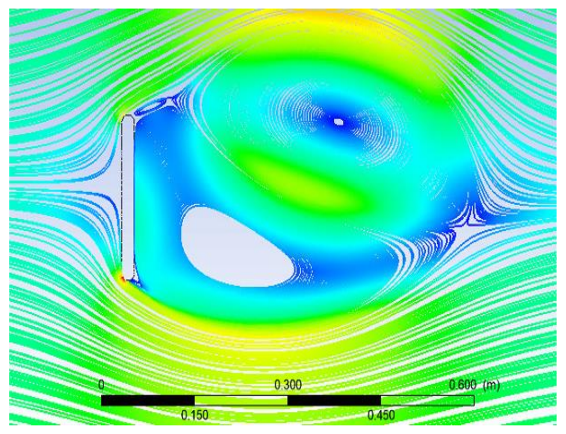

Fig.1a U=5m/s

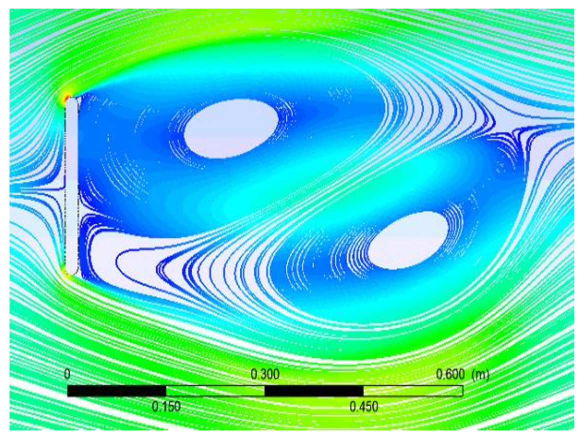

Fig.1b U=17m/s

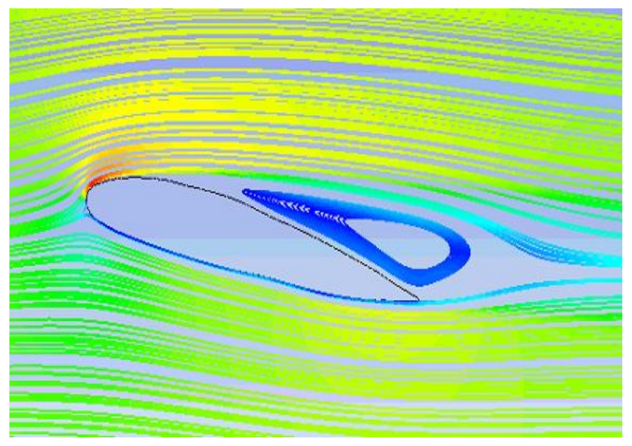

Fig.1c U=5-17m/s

- Detaching vortices have the same size for all Re.
- Stationary vortices are the same.
- Vortex intensity is linearly related to Re.

Finding 2: Induced Vortices Formed on Asymmetric Flows

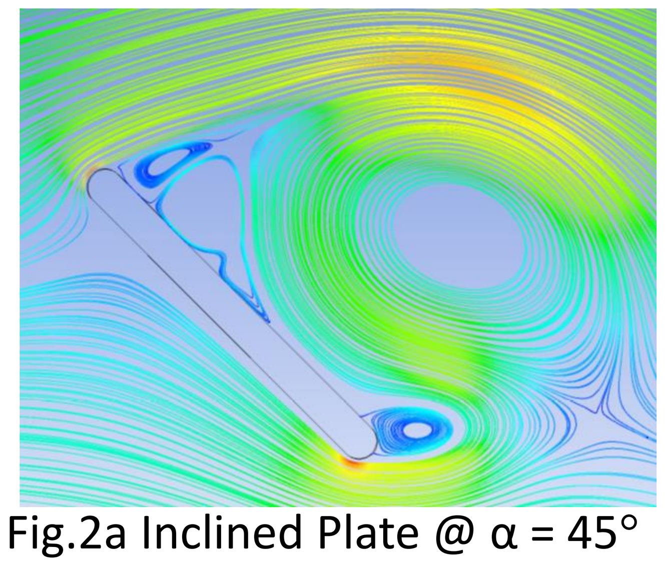

Fig.2a Inclined Plate @ α = 45°

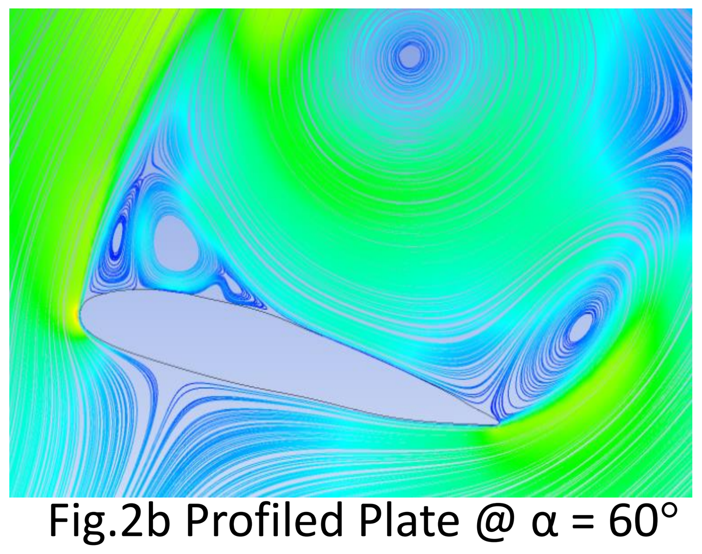

Fig.2b Profiled Plate @ α = 60°

- Asymmetry geometry causes biased flow and difference in vorticity at two plate tips .
- Small vortices are formed away from the plate tips induced by large vortices.
- The induced vortices merge with other vortex formed at the tip then detach, causing uneven vortex streak in the wake.

Finding 3: Vortex Not Able to Penetrate Honeycomb

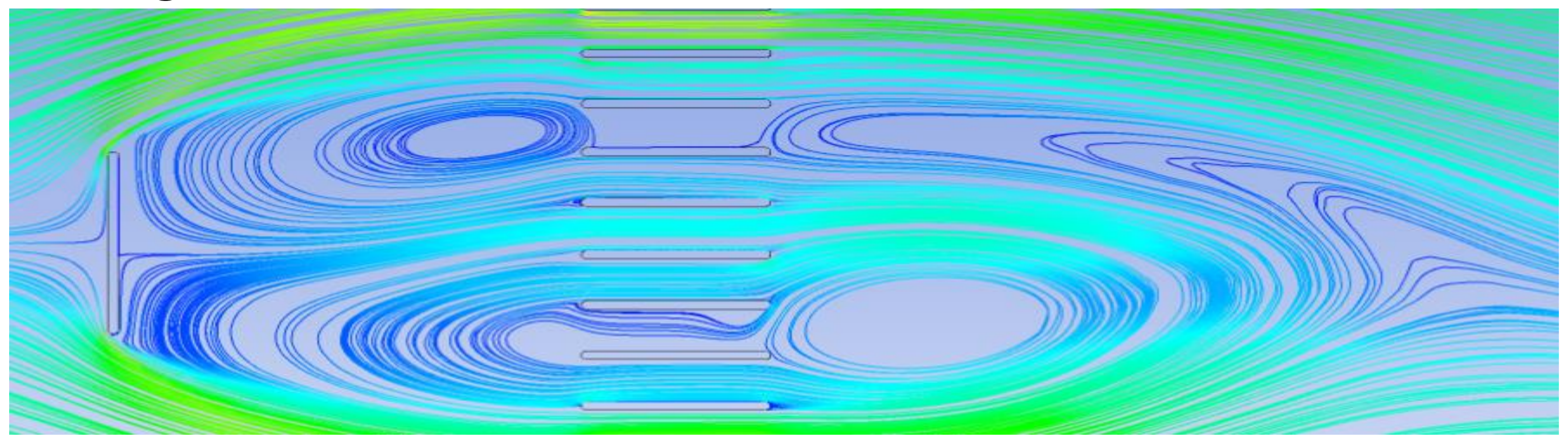

Fig.3a Shed Vortices Approaching Coarse Honeycomb

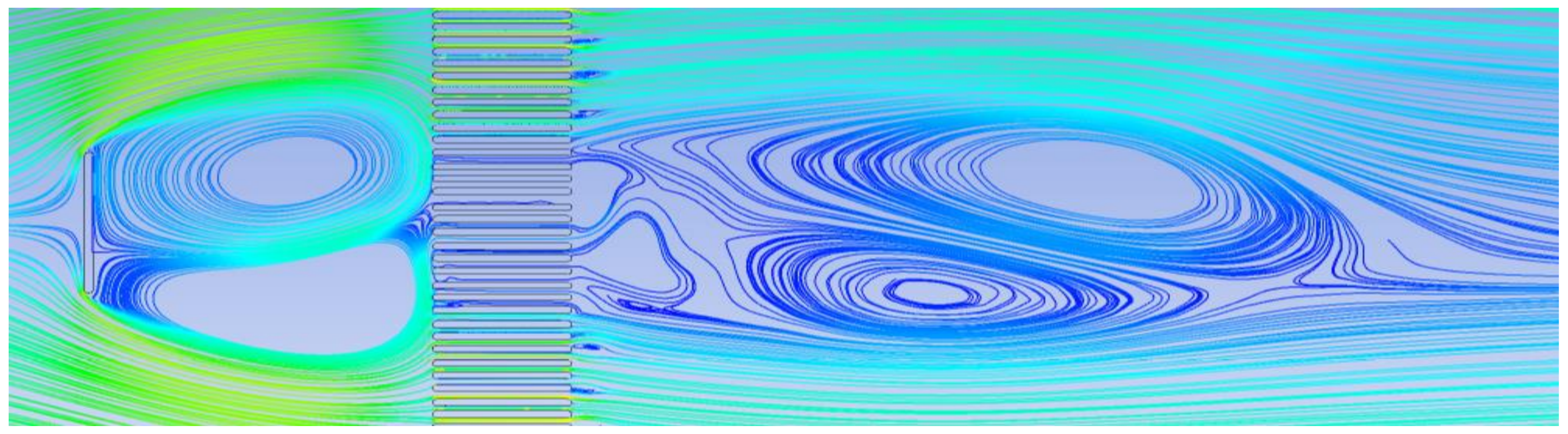

Fig.3b Fine Honeycomb

- ✓ Vortex eye may have encircled one or a few honeycomb partitions, but can never enter the slots, neither coarse or fine.
- ✓ Both velocity and vorticity are reduced in the flow behind the honeycomb.
- ✓ Vortex street may developed at a much reduced intensity behind the honeycomb.
- ✓ No vortex detachment takes place at the flat plate.

Finding 4: Vortices Elongated by Honeycomb

- Again no vortex detachment occur at the plate.
- Distance between flat plate and honeycomb is double in length of normal detached vortices
- Shed vortex pair stretched to full distance.

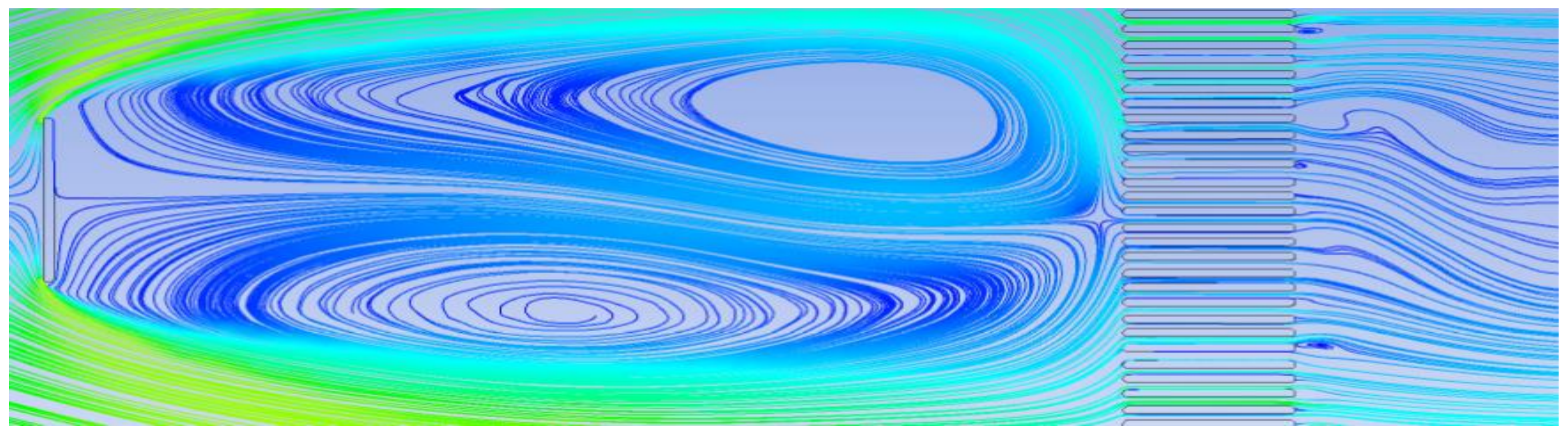

Fig.4 Shed Vortices Stretched Between Flat Plate and Honeycomb

Finding 5: Lively Vortex Activities with Honeycomb

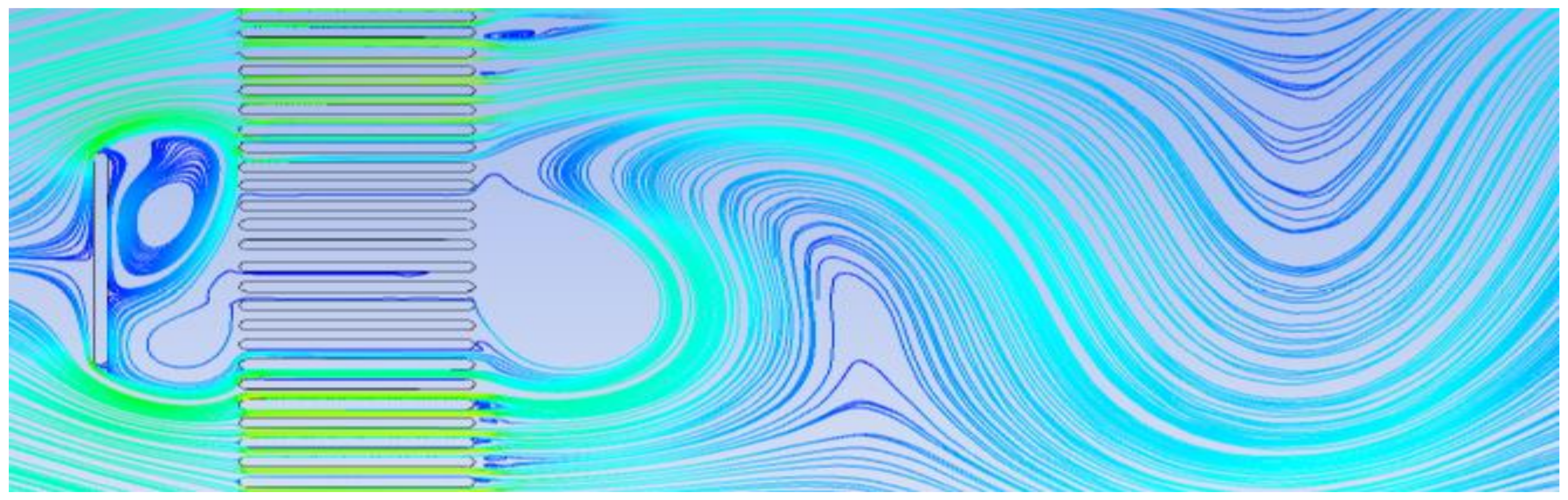

Fig.5 Vortex Street Formed behind Honeycomb

- Honeycomb close to plate
- Vortices active before and behind the honeycomb.
- No stagnation point.
- No vortex detachment.

Conclusions

A. A vortex does not shrink in size to enter small gap.
B. Slot walls reduce velocity on passing fluid.
C. Vortex shedding takes place by honeycomb partitions.

Postulations

Applying to 3-D flows in DAWT:

1. Vortex shed on turbine blade may not detach depending on the local angle of attack.
2. BTDWG may restrict BTV from penetration.
3. Diffuser wall may reduce flow velocity of BTV then may contain the intensity of BTV.
4. BTV may interact with stationary shed vortex on diffuser wall.

Further 3-D simulations are required to ascertain.